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cerned with the problem of determining correlation from material arranged in ranks. The most obviously simple way of dealing with any mass of statistical material is to arrange the individuals in a long row in order of ascending magnitude of some character. It is not even necessary that the character be accurately measurable on a quantitative scale to make such a row. The second, and on the whole most important of Pearson's new methods, shows how to deduce true variate correlation from the correlation of ranks. The method is less accurate than the usual product moment method. The third method deals with the determination of variate correlation from the positive difference of ranks. Regarding these last two methods Pearson's general conclusion is "that variate correlations found by ranks may prove to be a useful *auxiliary* method of dealing with correlation, when it is needful to give a rough answer to a problem in a brief time, or when the material itself is incapable of being accurately measured."

In connection with this matter of the analysis of statistics by the method of ranks or grades it is of interest to note that Galton has recently published a table[7] of deviates of the normal curve which will be found useful in practical statistical work. In the text accompanying the table (which is calculated by W. F. Sheppard) the use of the method of grades in dealing with material not susceptible of exact numerical measurement is discussed.

Of value for practical biometrical computing work is an editorial note[8] in the current number of *Biometrika* giving an easily calculated and extremely exact formula for the Γ function. This function is frequently used in statistical work, particularly in curve fitting.

RAYMOND PEARL.

PROTOZOA

Some Amœba Studies.—The amœboid organisms include a vast number of minute bits of glairy protoplasm which live in widely different places sometimes free in ponds and pools, sometimes confined as parasites, to the narrow limits of a single tissue. To group all of these living things under the one generic name of Amœba is to confess the weakness and artificiality of classification. Schaudinn[1] attempted to bring some order into the group by adopting Cassagrandi and Barbagallo's generic name Entamœba to cover the ordinary parasitic forms of the digestive tract. These differ from the common *Amœba proteus* quite as markedly as do other genera of rhizopods, and whether they differ generically among themselves is a matter to be decided only when the life histories are made out.

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[7] Galton, F. Grades and Deviates. *Biometrika*, Vol. V, pp. 440–406, 1907.

[8] On a Formula for Determining $\Gamma(x+1)$. *Ibid.*, Vol. VI, pp. 118–119, 1908.

Notwithstanding the hundreds of observations that are annually made on these amœboid organisms, there has been very little consecutive work on the changes of the protoplasm from beginning to end of the life cycle. Indeed, biologists would have extreme difficulty in picking up the thread of such a life history at either end, for observations and descriptions of conjugation or fertilization are most contradictory and confusing. The confusion will probably straighten out as soon as it is recognized that the varied accounts undoubtedly refer to quite different species or even genera of organisms. Schaudinn's description (*op. cit.*) of the process of fertilization in *Entamœba coli* was peculiarly daring, for autogamy amongst the unicellular animals was then a rare phenomenon, known to occur for a certainty only in Actinosphærium. Some such unusual process might be anticipated, however, in view of the fact that despite the thousands of eyes that annually study the amœboid forms, none have witnessed an ordinary form of conjugation amongst them. Schaudinn's excellent work on *Entamœba coli,* safeguarded by long experience with different kinds of protozoa study, and controlled by parallel studies on free-living rhizopods of other types must not be lightly brushed aside as too bizarre for serious consideration, especially as it has been confirmed in every detail by Wenyon[2] upon *Entamœba* (*Amœba*) *muris,* an intestinal parasite of the mouse.

According to Schaudinn, the cell of *Entamœba coli,* when mature, throws out all foreign matter and waste matter of its own metabolism, becomes more compact, smaller and spherical, and secretes a thick slightly refractive gelatinous membrane. The nucleus then divides by a primitive type of mitosis into two nuclei which are separated from one another by the entire diameter of the cell. The nuclei then fragment, forming chromidia, while the cell becomes incompletely divided into daughter cells. In some cases the entire nucleus of each half disappears in the mass of chromidia granules; in other cases there appears to be a secretion of the chromidial substance as in Arcella, but in all cases a portion of the nuclear material is thrown out of the nucleus to degenerate. From the chromidia granules a new and smaller nucleus is formed in each half of the cell. Each then divides by a primitive mitosis into two nuclei, one of which degenerates, the other divides a second time and again one of the resulting daughter nuclei degenerates. After this process, which Schaudinn interprets as the equivalent of reduction and polar body formation in metazoa, the final encystment takes place. The gelatinous membrane disappears and in its place a much more refractive cyst membrane is secreted. The contents of the cyst become closely united again and the two remaining nuclei are brought together. Then follows a third division by mitosis characterized by long connecting strands which lie parallel with one another in the center of the cell and so that the daughter nuclei lie side by side in pairs. These paired nuclei then fuse, an eighth part of one of the original nuclei uniting with an eighth part of the other. Each cyst thus contains two fertilized nuclei, each of which subsequently divides twice to form eight nuclei. In this condition the cyst passes into the intestine of a new host, where the protoplasm divides into eight spores each with one nucleus. Wenyon's account of *Entamœba muris* confirms Schaudinn's in all essential features.

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[1] F. Schaudinn. Untersuch. über d. Fortpflanzung d. Rhizopoden. Arb. a. d. Kais. Ges.-Amt., XIX, 3, 1903.

[2] C. M. Wenyon. Observations on the Protozoa in the Intestine of Mice. *A. f. Prot.,* Supp. 1, Festband R. Hertwig, 1907.

While *Amœba proteus* is probably far removed, phylogenetically, from Entamœba, there is reason to believe that the processes of fertilization have something in common. Four years ago Calkins[3] found what he regarded as evidences of a sexual phase in the life history, and described the multiplication of primary nuclei and the fragmentation of these nuclei into chromidia. The chromidia were interpreted as the possible nuclei of future gametes, an interpretation in line with the processes and outcome of chromidia formation in Foraminifera, in Arcella, Centropyxis, Difflugia and other rhizopods. Subse-

[3] G. N. Calkins. Evidences of Sexual Cycle in the Life History of *Amœba proteus*. *A. f. Protist.*, V, 1904.

quent observers, overlooking the fact that the stages in question must be very rare, have taken the ground, for the most part, that the evidence presented was too fragmentary to justify the conclusions reached. Some, like Schubotz,[4] while admitting the chromidia, claim that the organism is not *Amœba proteus*, and that the chromidia are not evidence of a sexual cycle; others like Prandtl,[5] forgetting that the cells under discussion were in a period of unusual physiological activity, attempted to explain them as pathological specimens with degenerating nuclei; and still others considered the scattered chromidia as possible parasites. The latter point of view was maintained by Prandtl[6] in a publication subsequent to the one just mentioned and in which the history of an Amœba-infesting parasite was made out. In this paper he hazarded the guess that the so-called multinucleate stage of *Amœba proteus* was in reality an ordinary form of Amœba infected with some species of Allogromia. This idea was undoubtedly suggested by the superficial resemblance between Prandtl's infected amœbæ and the photographs of the multinucleate *Amœba proteus*. Added experience would unquestionably have altered this conclusion, but the untimely death of this brilliant young investigator put an end to a career of great promise.

It was probably such experience that prompted Doflein to refrain from suggesting the possibility of an infection of *Amœba proteus* with some species of Dangeard's Nucleophaga. Doflein[7] found that the giant nucleus of *Amœba vespertilio* is a degeneration nucleus due to the presence of an intra-nuclear parasite *Nucleophaga amœbœa,* discovered by Dangeard in 1895, and he calls attention very properly to the possibility that many of the supposed chromidia in Amœba and allied forms may be parasites or stages of parasites of like nature. A similar parasite in the macronucleus of *Paramecium caudatum* was described by Calkins[8] as an intra-nuclear parasite similar to the intra-nuclear phase of the smallpox organism. But between this parasite and the chromidia of *Amœba proteus* there is not the slightest trace of resemblance.

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[4] H. Schubotz. Beiträge zur Kenntnis der *A. blattœ* und *A. proteus. A. f. Protist.,* VI, 1905.

[5] H. Prandtl. Die physiologische Degeneration der *Amœba proteus. A. f. Protist.,* VIII, 1907.

[6] H. Prandtl. Der Entwicklungskreis von Allogromia sp. *A. f. Protist.,* IX, 1907.

[7] F. Doflein. Studien zur Naturgeschichte der Protozoen. V. Amöbenstudien. *A. f. Protist.,* Supp. 1, Festband R. Hertwig, 1907.

[8] G. N. Calkins. The Life History of *Cytoryctes variolœ* Guar. In Councilman's Studies on Variola. *Jour. Med. Research,* 1904.

In the earlier paper it was supposed that the chromidia stage is only the antecedent of the later gamete formation and that conjugation of gametes is the method of fertilization. In a later paper Calkins[9] described some further studies made upon the same material after the amœbæ had been removed from the balsam, embedded in paraffine and sectioned. The supposed chromidia granules were then described as minute secondary nuclei which unite two by two, each couple giving rise to a reproductive body similar to a sporoblast. There were many gaps in this later account of fertilization and much remains to be done before the fertilization of *Amœba proteus* is established, but these later observations indicate a fundamental agreement with Schaudinn's description of fertilization in Entamœba. Chromidia formation seems to be an expression of some deeply lying biological activity concerned with the germ plasm and with fertilization. In some forms, as Arcella, Polystomella or Centropyxis, the nuclei of conjugating gametes are formed by the coalescence of such chromidia. In *Entamœba coli* there is a similar coalescence to form gametic nuclei, while fertilization is autogamous. In *Amœba proteus* the original nucleus of the cell divides repeatedly, the resulting nuclei break down into fragments, each of which is a complete gametic nucleus. Fertilization is again autogamous and chromidia formation s. str. absent.

It must not be forgotten in comparative studies of this kind that the organisms are widely different and that the expression of the fundamental biological activity underlying chromidia and fertilization is worked out in widely different ways. This obvious and trite observation has not been heeded in a recently published work on parasitic rhizopods by E. L. Walker.[10] Carried away, apparently, by success in raising amœboid organisms in large quantities by using artificial culture media recommended by Musgrave and Clegg, Walker has allowed to slip away a valuable opportunity to contribute something new to our knowledge of intestinal forms of rhizopods, while, on the other hand, he has allowed his imagination to lead him into generalizations involving totally different organisms. Here is one danger of the use of artificial culture methods in studying protozoa. The enormous numbers obtained tend to obscure the varying phases of vitality that characterize the life cycle of protozoa. The study of protozoa, even when it is possible to apply bacteriological methods, is fundamentally different from bacteria study. The latter dependent upon growth conditions, colony formation, reactions to media, etc., are essentially physiological. Protozoa study, on the other hand, is essentially morphological and is based upon the structures of the protozoan cell, involving all changes in cell structure which an individual (in the cyclical sense) undergoes during various phases of vitality. Hence it becomes necessary, first of all, to know the life history of a protozoon and the fundamental structures which its protoplasm assumes at different periods of vitality. Mere number of cells in any given phase is not satisfactory and here is where Walker falls into a trap. He fails to find stages described by Schaudinn and Wenyon, in his agar cultures and gives the inference at least that their observations were incorrect, all without taking the trouble to obtain his organisms in the corresponding stages of vitality. Schaudinn, in one set of observations to fill out the sexual phase of the life history, watched his material for weeks without finding the stages desired, and, to get them, finally swallowed the contents of a number of dishes, thus inoculating himself. His experiment was successful and he obtained what he wanted. This heroic method of procedure is not absolutely necessary, for abundant material may be obtained by inoculating lower animals; even such experiments, however, were not made apparently or, if made, not described by Walker. Such neglect vitiates all criticism or comment by the author, of conclusions of others regarding the sexual cycle of intestinal rhizopods and *a fortiori* of free-living *Amœba proteus,* an entirely different kind of organism.

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[9] G. N. Calkins. The Fertilization of *Amœba proteus*. *Biol. Bull.*, XIII, 1907.

[10] E. L. Walker. The parasitic Amœbæ of the Intestinal Tract of Man and other Animals. *Jour. Med. Research,* XVII, 1908.

Not even in regard to the ordinary vegetative phases of his organisms does Walker do justice to the material. The undoubted reproduction by budding is entirely overlooked; the term ''spore'' is misused throughout and the ''extrusion'' of fully formed reproductive bodies is very questionable. If such a method of endogenous bud-formation actually obtains, then, as an entirely new phenomenon in these rhizopods, it certainly deserves more than the superficial description which the author gives. It is difficult to conceive how the budding process could have been overlooked, for in Entamœba under culture on agar, this process is apparently the most common method of reproduction. It is quite probable that development of the extruded so-called "spores" as described is the actual development of such buds. The finer details of structure were not made out, the origin of chromidia granules and their fate are not described, owing, possibly, as the author admits, to faulty technique (p. 418). Much dependence is placed upon the *cyst,* but there is no evidence to indicate that the author is cognizant of the difference between temporary and permanent cysts. Many instances among protozoa might be cited of the wide difference existing in the two types and in the same species, and Schaudinn and others have previously called attention to these differences in the parasitic rhizopods. Hence the cyst, as a feature in the identification of species as Walker gives them, loses it value. Walker's long list of species finally, while a convenient summary of the described amœboid parasites, can not be accepted as established, and his several "new" species must share the same fate, for in no case has the full life history—the only adequate basis of species—been made out. When the full history is worked out, these many so-called species will probably be reduced to mere varieties, or to a few species of the genus Entamœba.

G. N. C.

EXPERIMENTAL ZOOLOGY

Regeneration.[1]—Professor Korschelt has brought together in compact, yet readable form, the more important results on regeneration and transplantation in animals and plants. No small amount of discrimination is required to put into 170 pages all the results so far obtained on regeneration both of animals and of plants; yet Professor Korschelt has shown unusual judgment in selecting the essential and typical results of the old and the recent work. Necessarily, much detail has been pruned away, yet the author has succeeded in bringing into proper correlation many widely scattered facts. The more theoretical and analytical sides of the problem occupy a very

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[1] Regeneration und Transplantation. By E. Korschelt. 1907.